

# Ames' contributions to STS-1: The Boldest Test Flight in History

April 12, 2006 marks a historic milestone on two continents in the human exploration of space. It is the 45th anniversary of the flight of Soviet cosmonaut Yuri Gagarin, the first human to orbit the Earth. It also is the 25th anniversary of STS-1, the first orbital flight of the Space Transportation System, or space shuttle.

STS-1 was the first piloted flight using solid rocket boosters, and the first U.S. space vehicle to carry a human crew on its maiden flight. STS-1 and the three flights following were engineering test flights to prove the space shuttle system in launch, orbital and landing operations.

The primary flight objective was to demonstrate safe launch into orbit and return to landing of Columbia and its crew. Secondly, the flight verified the combined performance of the entire vehicle -- orbiter, solid rocket boosters and external tank -- through separation and retrieval of the spent solid rocket boosters.

A major portion of the flight and detailed test objectives was aimed toward 'wringing out' orbiter hardware systems and their operating computer software, and toward measuring the overall orbiter thermal response while on orbit with payload doors open and closed. Still other test objectives evaluated the orbiter's attitude and maneuvering thruster systems and the performance of the spacecraft's guidance and navigation system.

Research at Ames played a key role in the development and evolution of the space shuttle program from the very beginning. The shape of the orbiter has its roots in the 'lifting body' research pioneered by Ames. Once its 1- to 2-week orbital mission is complete, the shuttle executes a de-orbit burn, which slows it for its descent into the atmosphere. Initial entry occurs at about 25 times the speed of sound in air. The vehicle executes a 'blunt body entry' maneuver pioneered by Ames' second director, H. Julian "Harvey" Allen.



STS-1 launched from KSC on April 12, 1981, with Commander John Young and pilot Robert Crippen.

The center's major contributions to the early development of the space shuttle leading up to STS-1 include contributions to the shuttle ascent aerodynamics/aerothermodynamics (a combination of aerodynamics and thermal effects), the thermal protection system (TPS) that prevents the orbiter from burning up during reentry, low-speed approach and landing technology and simulator research.

## **Aerodynamics of the Orbiter/Boeing 747 Ferry Configuration**

One of Ames' first tasks was to understand the aerodynamics of the specially modified Boeing 747 used to ferry the orbiter from Dryden to Kennedy Space Center. The aerodynamics of the mated vehicles and the interference of flows between the vehicles had to be well understood prior to committing to design and flight. Testing in Ames' 14-foot wind tunnel was a major contribution to the successful flight test of the 747/full-scale orbiter model Enterprise.

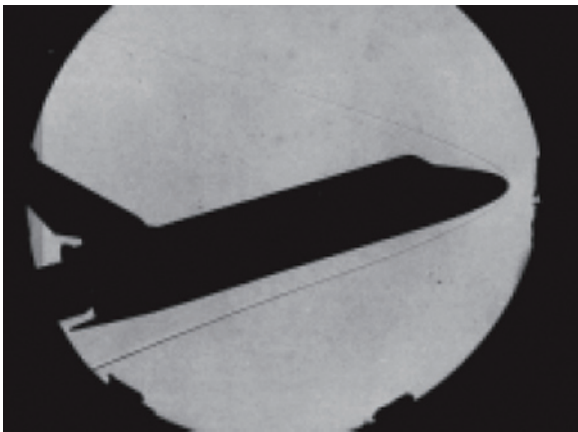
## Ascent Aerodynamics/Aerothermodynamics

More than 50 percent of the wind tunnel testing conducted for the shuttle was done at Ames. Nearly all the aerodynamic studies at Ames used the center's extraordinary collection of wind tunnels, including the 40-by 80-foot wind tunnel, 12-foot pressure wind tunnel, the 2-foot, 11-foot and 14-foot transonic wind tunnels, the 6-by-6 foot, 8-by-7-foot and 9-by-7-foot supersonic wind tunnels, and the 3.5-foot hypersonic wind tunnel. Ames wind tunnels supported more than 35,000 hours of wind tunnel testing of shuttle design and construction.

One of the most heavily used tunnels for shuttle testing was the 3.5-foot hypersonic wind tunnel. This facility provided about 47 percent of the total hours of wind tunnel testing at Ames. These studies led to the understanding of many different complex phenomena, including dynamics of shock-shock interactions caused from the proximity of the elements of the stack configurations, and the effects of split body flap deployments and turbulent flows.

## Entry Aerodynamics and Aerothermodynamics

Before the space shuttle, most entry vehicles were relatively simple, blunt shapes with no aerodynamic control surfaces. The shuttle was to become the first airplane-like entry vehicle with movable control surfaces.



Shadowgraph of flow about the shuttle orbiter at Mach 7 showing the bow shock wave.

The 3.5-foot hypersonic wind tunnel contributed equally to both ascent and entry aerodynamics and entry aerothermodynamics. At higher Mach numbers, shock-heated gases create an environment that would melt the surface of the vehicle were it made of materials such as aluminum or composites found in modern aircraft. Data and analyses from Ames' wind tunnel simulations later were used to refine methods for estimating the heating over the full-scale shuttle.

The entry aero/aerothermodynamics of the shuttle were performed before the advent of modern 3-dimensional computational fluid dynamics, a later accomplishment led by Ames. In the 1970s, personnel used approximate analytical tools, experimental results and engineering judgment to model the aerodynamic forces, heating rates and heating loads to understand the shuttle entry flow environment. This knowledge was required for the development of the shuttle TPS, another area of key contribution by Ames.

## Thermal Protection System Contributions

The shuttle's thermal protection system prevents the vehicle from burning up from the searing heat of hot gases that exist within a bow shock layer that envelops the vehicle as it re-enters Earth's atmosphere. These gases reach temperatures as high as 25,000 degrees F, and heat the surface of the vehicle to as much as 3,000 degrees F.

In the early 1970s, Ames and JSC evaluated a large number of candidate TPS materials for the space shuttle orbiter in their arc jet facilities. Among these new types of heat shield materials was the LI-900 silica tile system developed by Lockheed Missiles and Space Company (LMSC), Sunnyvale. In order to understand why the various tile materials performed as they did in arc jet testing, Ames began a tile analysis research and development program. When the LI-900 tile system was chosen as the baseline in 1973, Ames had already begun to make significant contributions to TSP technology.

In 1975, Ames invented the black borosilicate glass coating called Reaction Cured Glass that now covers two-thirds of the orbiters' surface. This coating covers the tile and radiates away heat. The finished tile substrate resembles Styrofoam, but its thermal properties are such that the surface can be glowing white hot at more than 2,300 degrees F and the back face of the tile never exceeds 250 degrees F, only a few inches below the surface.

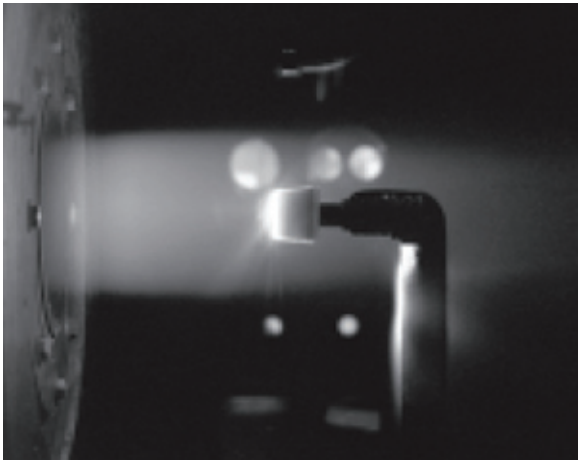
In 1974, Ames invented the tile now known as LI-2200, which is stronger than LI-900 and provides improved temperature capability. Adopted in 1978, this new tile replaced about 10 percent of the baseline LI-900 tile system on the first orbiter, Columbia. In 1977, Ames invented a new class of tiles called Fibrous Refractory Composite Insulation. In 1980 it replaced about 10 percent of the earlier LI-2200 and LI-900, providing a more durable TPS and saving about 500 pounds of the overall TPS weight.

Hot gas flow between the tiles during atmospheric entry was considered a serious problem during orbiter development. In response, Ames developed a gap filler, which consists of a ceramic cloth impregnated with a silicone polymer that was adopted as a solution to the gap heating for Columbia. The Ames gap filler was so successful that it was adopted as a permanent solution to the gap flow problems on all the orbiters. More than 10,000 are now used on each vehicle.

On the leeward side of the orbiter, gases are much cooler during entry. Ames (with Johns Manville) developed a flexible silica blanket insulation that was retrofitted to Columbia.

### Arc Jet Facilities Simulate Entry Heating

Arc jets are facilities used to simulate the entry heating that occurs for locations on the body where the flow is brought to rest (typically on the nose cap, wing leading edges and on the acreage of the vehicle). Simulations have to run from a few minutes to tens of minutes to understand the TPS materials' response to the hot gas flow environment. Ames' ability to test a 2-foot by 2-foot section of the acreage tile field in conditions duplicating aeroconvective heating and reacting boundary layer chemistry during simulated entry conditions was a critical element in the development of shuttle TPS.



Stagnation point test

### Low-Speed Descent Aerodynamics

Still glowing red hot from its high-speed entry, the orbiter slows and descends into the supersonic/transonic/subsonic regime of its return. Again, Ames' wind tunnels played a key role in defining shuttle aerodynamics and design of the orbiter. The 2-foot transonic wind tunnel was used to study potentially troublesome panel flutter problems. The 12-foot pressurized wind tunnel was used to investigate



36 percent orbiter model in the 40-foot by 80-foot wind tunnel

the orbiter's low-speed handling characteristics.

Ames' efforts demonstrated that unpowered landings could be made at speeds of at least 200 knots without significant problems. The 12-foot wind tunnel was used to define the aerodynamics of a specially modified Gulfstream 2 business jet. This vehicle was used for flight tests and astronaut training. The Gulfstream, now known as the STA (Shuttle Training Aircraft), is used to this day by pilot astronauts for in-flight proficiency training.

Finally, an awesome 36 percent scale model of the orbiter, 44 feet long, was fabricated and tested in Ames' 40- by 80-foot wind tunnel. An important purpose of the 40-by 80-foot testing was to identify the influence of the TPS on the orbiters' low-speed aerodynamics. This model still exists, painted with the striking black underbelly and white top. It is proudly displayed in front of the former Ames Visitor Center, near the 40-foot-by 80-foot wind tunnel where it was so intensely tested.

### Approach/Landing Systems Development: FSAA

Landing simulation research for the shuttle orbiter began in the very early 1970s, using the Flight Simulator for Advanced Aircraft (FSAA). The large motion envelope of the FSAA provided many of the vital cockpit accelerations that enabled pilot astronauts to experience a truer 'feel' of the g-forces of the orbiter during approach and landing.

For many years, prior to first flight, all the pilot astronauts who would eventually fly the orbiter spent many hours in the FSAA, identifying handling qualities that needed improvement, and control system shortcomings. In this process, the pilots gained invaluable training in the skills needed to successfully land the orbiter.

A pilot-induced oscillation (PIO) problem arose on the first approach and landing test program flight in July 1977. A PIO is a longitudinal 'porpoising' that worsens due to pilot over-control. It is generally not a piloting technique problem so much as a control system problem. On this first flight, as the oscillation began to diverge dangerously close to the ground, the pilot had enough confidence and simulator training to simply let go of the controls and allow the oscillation to damp itself out. Following that, a major investigation was conducted in the FSAA to re-evaluate the control systems gains, in order to minimize the possibility of future PIO problems.

## Vertical Motion Simulator

In 1980, Ames' new Vertical Motion Simulator (VMS) began operation. It wasn't long before the VMS earned a reputation as the best simulator anywhere for the continuation of engineering design and shuttle pilot training. Landing systems and flight rules are done on the VMS with astronaut crews and JSC engineers. Ames' SimLab and VMS have supported the shuttle program on a continuing and scheduled basis ever since.

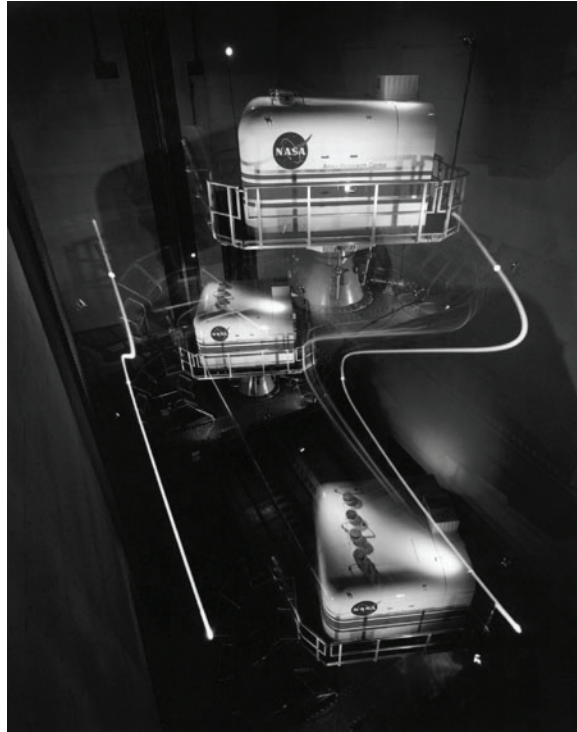
## Conclusion

On April 14, 1981, commander John Young and pilot Robert Crippen brought space shuttle Columbia to a safe landing at Dryden Flight Research Center. STS-1's mission duration of 2 days, 6 hours, 20 minutes and 53 seconds included 37 orbits of the Earth.

This first, brief mission proved the capability of the world's first and only reusable space vehicle. It successfully tested the Space Transportation System's major systems and demonstrated the safe launch into orbit and safe return of the orbiter and crew. It also verified the combined performance of the shuttle orbiter, solid rocket boosters and external tank.

The talented professionals at Ames are continuing to provide essential skills and facilities to support the

human space program. Current projects consist of work on the crew exploration vehicle (CEV) thermal protection system, CEV aerosciences analysis, CEV integrated system health management, crew cabin and cockpit display development, CEV guidance, navigation and control software verification and validation, crew launch vehicle (CLV) simulation assisted risk analysis, and CLV integrated system health management.



"Streak" photograph of the simulator showing how the piloted cabin moves to give the "feel" of flight and

National Aeronautics and Space Administration

**NASA Ames Research Center**  
Moffett Field, California, 94035